3D Aerosol-Clouds Radiative Interaction and the Role of Molecular Scattering In Enhancing Clear Region Refletance in Cumulus Cloud Fields

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Executive Summary

We apply Monte Carlo method for radiative transfer to study cloud-induced enhancement in clear region of boundary layer cumulus cloud as observed by MODIS and ASTER in biomass burning regions in Brazil. 3D radiation fields are computed using MODIS and ASTER derived cloud optical depth. We found

1. Cloud illumination and shadowing effects near cloud edges are large and variable.
2. Cloud-induced enhancement become less variable about 2-3km away from cloud edges.
3. 3D cloud-induced enhancment depends on optical properties of nearby clouds as well as wavelength with associated biased error in 1D AOT retrieval ranges from +50% to +140%.
4. Detailed analyses show that radiative interaction between cloud and molecule above is the major mechanism for cloud-induced enhancement.

Data Sets

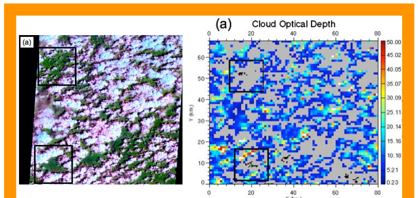


Figure 1. (Left) ASTER image centered at (0ºN, 53.78ºW) acquired on January 25, 2003; (Right) MODIS cloud optical depth fields for collocated ASTER images. The solar zenith angle is 32º.

MODIS Aerosol Retrievals and ASTER COD

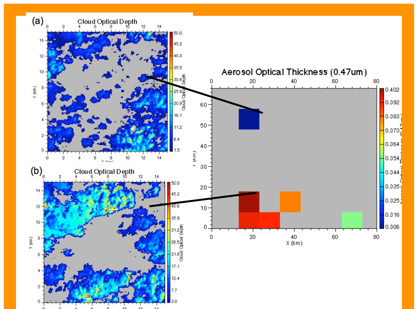


Figure 2. MODIS AOT (~0.4) in **thick** clouds (τ~14) is considerably larger AOT (~0.3) in **thin** clouds (τ ~7)

Quantify 3D Cloud Effects at 0.5 km Resolution

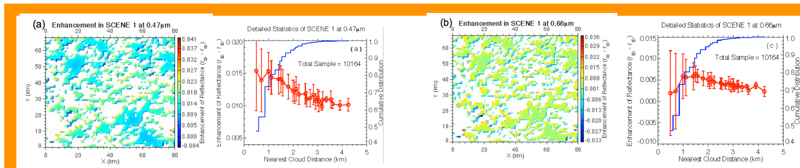


Figure 3. 3D cloud-induced enhancement for clear region in the cumulus above with detailed statistics for all non-cloudy pixels and MODIS selected pixels below.

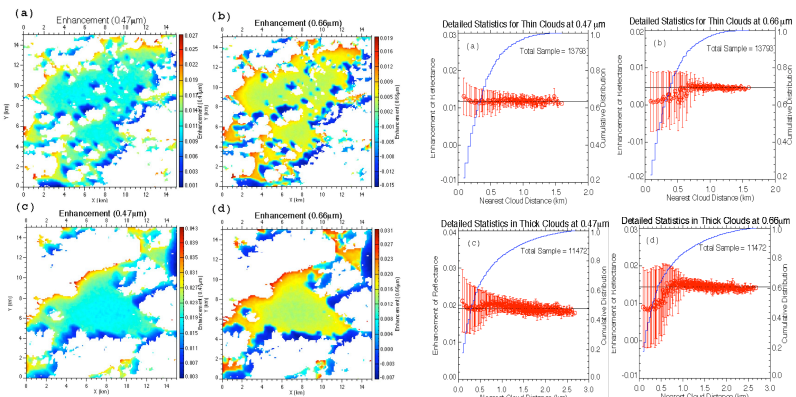
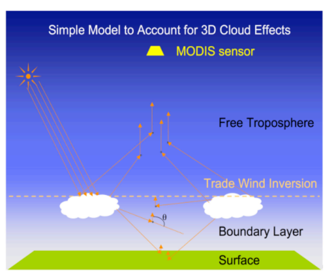
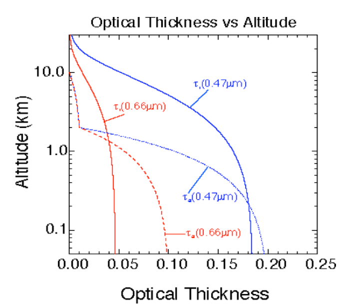


Figure 4. The 3D cloud-induced enhancement in reflectance will lead to overestimates of AOT of $\Delta\tau(0.47\mu m)$ ~0.12 and $\Delta\tau(0.66\mu m)$ ~0.043 in thin clouds; and $\Delta\tau(0.47\mu m)$ ~0.19 and $\Delta\tau(0.66\mu m)$~0.14 if 3D cloud effects are ignored. For true $\tau(0.47\mu m) = 0.2$ and $\tau(0.66\mu m) = 0.1$, the1D approximation systematically overestimate AOT by +50% to +140%.

Simple Model and Optical Depth Distribution





Identify the Major Mechanism

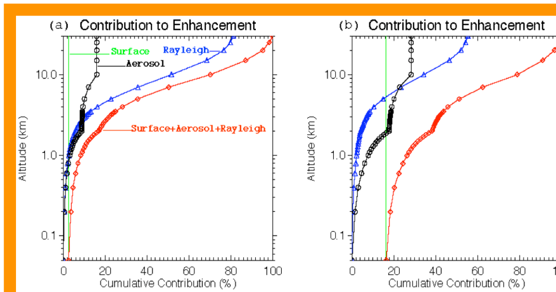


Figure 5. The cumulative contribution to the enhancement in **thick** cumulus (a) for wavelength at $0.47\mu m$; and (b) for wavelength $0.66\mu m$.

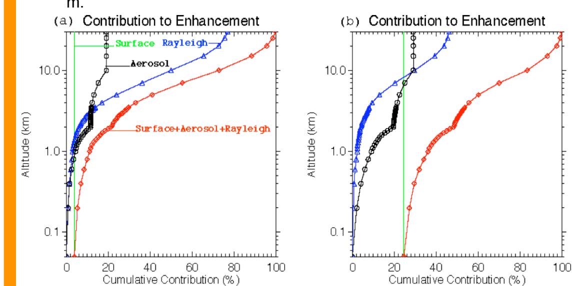


Figure 6. The cumulative contribution to the enhancement in **thin** cumulus (a) for wavelength at $0.47\mu m$; and (b) for wavelength $0.66\mu m$.

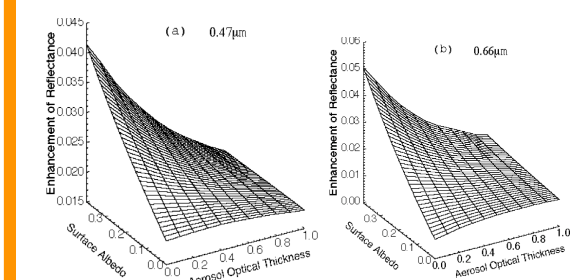


Figure 7. The total reflectance enhancement ($\Delta R = R_{3D} - R_{1D}$) in **thick** cumulus as a function of aerosol optical thickness and surface albedo.